average cut length of grains was measured by counting intersection points of the scanning linear line and grain boundaries. On the other hand, a cut length of the largest grain was measured in five fields of view in a microstruture photograph of 200 times (7 cm×10 cm)at a random position on the same sample. The samples, in which the ratio of the cut length of the largest grain to the average cut length is 3 or more, were classified into the group of abnormal grain growth, while the samples with the said ratio of not more than 3 were classified into the group of no abnormal grain growth.

In case of the C125grade, using steel "a" and steel "b", the samples of test Nos. 35 and 36, which were manufactured in a process corresponding to the conventional process of reheating and quenching after rolling, do not have satisfactory SSC-resistance. On the contrary, the samples of test Nos. 1–6, manufactured in a process corresponding to the process of this invention, have excellent SSC-resistance and toughness which had not been obtained in the conventional process.

In case of comparative examples, test Nos. 25–29, the working and/or heat treating conditions were out of those of this invention. Any sample of these test numbers does not have sufficient SSC-resistance. The abnormal grain growth was found in some samples and toughness and Sc values are low. Furthermore, there were some samples of very low strength such as the sample of test No. 29.

Next, the properties of samples of steels "e", "n", "f", "l" and "o" which were adjusted to the C140 grade are as follows:

Test Nos. 37–42 are examples produced in the conventional process comprising the steps of reheating and quenching after rolling. These samples have good properties in Sc value and toughness, but all of these were broken in the constant load test of Method-B.

Samples of test Nos. 30–34 were comparative examples which were produced under conditions of working and heat treating out of those defined in this invention. All of these samples do not have satisfactory SSC-resistance. Abnormal grain growth was found in some samples, and toughness and Sc value are poor. There was an example of very low strength such as the sample of test No. 34. However, the excellent SSC-resistance which has not been attained in the conventional process was obtained in the samples produced in the process of this invention shown as test Nos. 7–24.

In the examples subjected to the intermediate heat treatment after the in-line quenching, under the condition of this invention, it was found that Sc value and toughness were improved by the refining of grain structure, although there could not be found so large difference in test results of METHOD-A of the C125 grade samples (test Nos. 2, 3, 5 and 6) or the C140 grade samples (test Nos. 8, 9, 11, 12, 14, 15, 17, 18, 20, 21, 23 and 24).

INDUSTRIAL APPLICABILITY

The process for producing a seamless steel pipe, according to this invention, is the process wherein the pipe manufacturing and the heat treating thereof are carried out in one production line. Accordingly, the effect of process shortening and energy saving is much larger compared with the conventional process comprising the off line reheating and quenching steps.

Furthermore, the properties of the seamless steel pipe produced in this process are equal or superior to those of the pipe which is manufactured in the conventional reheating, quenching and tempering process. At this point the process of this invention is superior to the usual direct quenching process.

According to this invention, it is able to produce seamless steel pipes corresponding to not only the C110 grade, but also the C125 grade or over, having high strength and excellent SSC-resistance, at low cost. This invention contributes for a stable energy supply by decreasing the cost of oil well development, especially by promoting the development of very deep oil wells which used to be difficult to develop.

We claim:

1. A process comprising steps of hot piercing and hot rolling for producing a high strength seamless steel pipe, having excellent sulfide stress cracking resistance, characterized by using a billet of low alloy steel which contains, in weight %, 0.15–0.50% of C, 0.1–1–1.5% of Cr, 0.1–1.5% of Mo, 0.005–0.50% of Al, 0.005–0.50% of Ti and 0.003–0.50% of Nb, and comprising the followings steps:

(1) hot piercing the billet into a hollow shell,

(2) hot rolling the hollow shell with 40% or more of cross sectional reduction ratio,

(2) the hollow shell

(3) finishing the hot rolling in a temperature range of 800–1100° C.,

(4) putting the manufactured steel pipe promptly in a complementary heating apparatus after the finish rolling, and complementarity heating at the temperature and time satisfying the following formula (a),

(5) quenching the steel pipe immediately after taking out of the complementary heating apparatus, and

(6) tempering the pipe at a temperature not higher than the Ac_1 transformation point as the last heat treatment,

$$23500 \leqq (T+273)\times(21+\log t) \leqq 26000 \qquad (a)$$

where, T (°C.) is a temperature of not lower than 850° C., and t is a time (hr).

2. A process for producing a high strength seamless steel pipe, having excellent sulfide stress cracking resistance according to claim 1, characterized by further comprising one or more times intermediate heat treating which consists of quenching or combination of quenching and tempering, between the above-mentioned quenching step (5) and the last heat treatment step (6).

3. A process for producing a high strength seamless steel pipe, having excellent sulfide stress cracking resistance according to claim 1, characterized by using the steel billet which consists essentially of, in weight %, 0.15–0.50% of C, up to 1.5% Mn, 0.1–1.5% of Cr, 0.1–1.5% of Mo, 0.005–0.50% of Al, 0.005–0.50% of Ti, 0.003–0.50% of Nb, up to 0.010% of N, up to 0.01% of O, up to 0.05% of P, up to 0.01% of S, up to 0.1% of Ni, up to 0.5% of V, up to 0.5% of Zr, up to 0.01% of B, up to 0.01% of Ca, up to 2.0% of W, and the balance of Fe and incidental impurities, and each amount of Ti, Zr and N is defined by the following formula (b).

$$Ti(\%)-(48/14)\times\{N(\%)-(14/91)\times Zr(\%)\} \geqq 0 \qquad (b)$$

4. A process for producing a high strength seamless steel pipe, having excellent sulfide stress cracking resistance according to claim 3, wherein the steel billet further contains 0.05–0.5 weight % of V.

5. A process for producing a high strength seamless steel pipe having, excellent sulfide stress cracking resistance according to claim 3 or claim 4, using the steel billet in which Si content or Mn content is not more than 0.1 weight % respectively, or both of Si content and Mn content are not more than 0.1 weight %.

6. A process for producing a high strength seamless steel pipe, having excellent sulfide stress cracking resistance according to claim 3, or claim 4, using the steel billet in which P as an impurity is not more than 0.005 weight %, or S as an impurity is not more than 0.0007 weight %, or P as an impurity is not more than 0.005 weight % and S as an impurity is not more than 0.0007 weight %.

7. A process for producing a high strength seamless steel pipe, having excellent sulfide stress cracking resistance according to claim 5, using the steel billet in which P as an impurity is not more than 0.005 weight %, or S as an impurity is not more than 0.0007 weight %, or P as an impurity is not more than 0.005 weight % and S as an impurity is not more than 0.0007 weight %.

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